



# IEUBK Model Mass Fraction of Soil in Indoor Dust ( $M_{SD}$ ) Variable

## STATEMENT OF THE ISSUE

The  $M_{SD}$  is a variable in the dust lead (PbD) *Multiple Source Analysis* module of the Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children (see IEUBK model data entry window: *Data Entry for Soil/Dust, Multiple Source Analysis, Contribution of soil lead (PbS) to indoor household PbD [conversion factor]*). The  $M_{SD}$  represents the mass fraction of house dust that is derived from outdoor soil. It is used in *Multiple Source Analysis* to compute the contribution of outdoor PbS to the indoor PbD concentration. The default value for  $M_{SD}$  recommended by EPA is 0.70 g soil/g dust. The *Multiple Source Analysis* input screen for the IEUBK model (version 0.99d; 3/8/94) and IEUBK Model Guidance Manual (U.S. EPA, 1994; pp. 2-13) indicate that the  $M_{SD}$  can be expressed as a dust lead/soil lead concentration ratio (PbD/PbS;  $\mu\text{g Pb/g dust per } \mu\text{g Pb/g soil}$ ). However, this guidance may be subject to misinterpretation; therefore, this report clarifies and supplements the IEUBK Model Guidance Manual.

$M_{SD}$  is equivalent to the PbD/PbS concentration ratio under exposure scenarios where soil is the predominant source of Pb in house dust and where there is no enrichment of the Pb in soil materials transported indoors in comparison with sampled soils (U.S. EPA, 1994; pp. 2-13). In scenarios where non-soil sources are also important contributors to indoor PbD (e.g., lead-based paint, non-soil airborne particulates),  $M_{SD}$  represents the contribution of soil to dust; and total PbD levels will exceed those resulting from the soil pathway alone. In order to promote consistency in the use of site-specific data to determine IEUBK model inputs, the  $M_{SD}$  should be interpreted as the mass fraction of household dust that is derived from soil; and the PbD/PbS ratio should be viewed as a potentially useful estimator of  $M_{SD}$  that is subject to various sources of bias.

## BACKGROUND

Soil is a primary source of indoor dust in many residences. Because of the potential for Pb in soil to be transported indoors and contribute to the concentration of Pb in dust, the IEUBK model incorporates a soil-to-dust variable ( $M_{SD}$ ). The  $M_{SD}$  is defined as the mass fraction of soil-derived particles in indoor dust (g soil/g dust).

Values of the  $M_{SD}$  are fractions bounded by the values 0 and 1. A relatively low value would reflect a scenario in which soil contributes little to indoor dust mass, whereas a relatively high value would suggest that soil is the predominant source of dust.

The  $M_{SD}$  may be used to approximate the concentration of Pb in indoor dust based on the concentration of Pb in nearby soil if the following assumptions are valid at the site:

- (1) Soil lead is the major source of indoor dust lead.
- (2) The soil data are representative of that portion of the soil fraction and matrix which contributes to indoor dust. There is no enrichment or reduction of Pb in the soil fraction that is transported to indoor dust.
- (3) The areas where soil samples are collected coincide with the major source areas for soil derived indoor dust. If the above assumptions are appropriate for a site and the exposure scenarios under consideration, then the dust Pb concentration can be estimated from Equation 1:

$$Pb_D = M_{SD} \cdot Pb_S \quad \text{Equation (1)}$$

where:

- PbD = indoor dust lead concentration ( $\mu\text{g Pb/g dust}$ )
- PbS = outdoor soil lead concentration ( $\mu\text{g Pb/g soil}$ )
- $M_{SD}$  = mass fraction of soil in dust (g soil/g dust)

When there are also other significant sources of Pb in indoor dust, the  $M_{SD}$  is useful for estimating the contribution that soil makes to house dust levels. This estimate will often be important to soil cleanup goals, where  $M_{SD}$  can be used to estimate the amount by which PbD concentrations can be reduced through soil cleanup. However, where there are other significant sources of Pb in dust, attempts to use measured Pb concentration data for soil and dust to estimate  $M_{SD}$  become more problematic.



The default value of 0.70 for  $M_{SD}$  in the IEUBK model reflects an analysis of empirical relationships between soil and dust Pb concentrations measured in a variety of residential communities (U.S. EPA, 1994; pp. 2-42). An intuitive understanding of the movement of outdoor soil is that the contribution to the total indoor dust mass from outdoor soil is also approximately of the same magnitude or greater when there are no other significant sources of indoor dust; that is, the primary contributor to the indoor dust mass is outdoor soil. However, further studies are needed to confirm the magnitude of the mass movement of soil. The  $M_{SD}$  may be strongly influenced by factors that affect soil deposition rates in homes, including: (1) the number of children and pets that may track soil indoors; (2) environmental factors such as climate (e.g., local rain and wind patterns); (3) the extent of vegetative cover of residential yards; and (4) the deposition of soils transported from neighboring properties. In addition, use of dust control measures may affect the  $M_{SD}$  and surface Pb loadings. Effective dust control measures include removal of shoes at the entry way, use of a quality door mat, and frequent use of an efficient vacuum (Roberts *et al.*, 1991; Roberts and Dickey, 1995). Temporal variability in the above factors at a residence will contribute to intra-residence variability in the  $M_{SD}$ , whereas variability in the above factors from residence to residence will contribute to inter-residence variability in the  $M_{SD}$ . Intra- and inter-residence sources of variability will increase the uncertainty of extrapolating empirical estimates of the  $M_{SD}$  from one residence to another, from one site to another, and from present to future circumstances at a given site.

It should be noted that the validated geometric standard deviation (GSD) values for the IEUBK model were estimated using model applications with measured soil and indoor dust concentration data. Measured dust data are affected by the differences in patterns of the indoor transport of soils at actual residences. Dust lead concentrations predicted using an estimated (fixed)  $M_{SD}$  do not incorporate residence to residence difference in dust transport. This variability in dust concentrations would tend to contribute to additional variability in Pb exposures and hence additional variability in PbB levels beyond that predicted using an estimated  $M_{SD}$  and the model geometric standard deviation. This observation indicates that risks of elevated PbB levels may be underestimated by model runs where matched soil and indoor dust measurements are not available and  $M_{SD}$  is based on a central value for a community. For this reason, assessments that seek to develop "health protective" soil cleanup goals should give weight to selecting an  $M_{SD}$  value at the higher end of the range of values that may be appropriate for the site. This document does not address methods for dust sampling,

however, the reader should be aware that dust sampling methodology and apparatus can have a significant impact on measured PbD levels. For example, unsieved dust samples, particularly when collected with high air-flow-rate vacuums, may contain paint chips (which could significantly increase measured PbD concentrations) or fibrous organic material (which would tend to reduce measured PbD concentrations). The Technical Review Workgroup for Lead (TRW) intends to provide data and recommendations on dust sampling methods in a guidance document on sampling for lead.

#### **DISCUSSION: APPROPRIATE APPLICATION OF $M_{SD}$ USING THE IEUBK MODEL**

As previously stated, the  $M_{SD}$  estimate is influenced by numerous site-specific factors. The IEUBK model may be used to assess risks associated with childhood exposure to Pb using measured environmental Pb concentrations in a residential community, as well as to establish PbS cleanup goals. The appropriate application of the  $M_{SD}$  under both contexts is discussed later in this document, under *Applications of the  $M_{SD}$  to Baseline Lead Risk Assessments* and *Applications of the  $M_{SD}$  to Soil Lead Cleanup Goals*.

#### **Issues Associated with Estimating a Site-Specific $M_{SD}$**

Empirical approaches to estimating a site-specific  $M_{SD}$  include: (1) extrapolation from PbD/PbS ratios measured in neighborhood residences in which non-soil sources of Pb are not likely to make an important contribution to indoor PbD (e.g., homes without lead-based paint); (2) regression analysis of paired data on Pb in soil, indoor dust, and other potential covariables; and (3) speciation of Pb in soil and indoor dust to identify and quantify soil-derived Pb in indoor dust. Sampling protocols for estimating  $M_{SD}$  should be designed to minimize the number of assumptions attributed to the  $M_{SD}$  to the greatest practicable degree.

#### **Extrapolation from PbD and PbS Data for Residences That Have Minimal Non-soil Lead Sources**

If it is possible to identify a subset of residences at which there is some certainty that soil is the major contributor to indoor PbD, then an estimate for the site  $M_{SD}$  can be obtained from the PbD and PbS concentrations measured at these residences. For example, at a site where lead-based paint is the major non-soil contributor to indoor PbD, a subset of residences without appreciable lead-based paint might be identified. An estimate of the ratio of the mean dust concentration to the mean soil



concentration in these houses may be used to develop a central value for  $M_{SD}$  in the community. Alternately, when soil and/or dust concentration data contain "outliers" that may affect the mean calculations, a second approach should be considered. The typical (median) PbD/PbS ratio in these homes would provide an indicator for the typical  $M_{SD}$  value that is less sensitive to outliers. Both of these approaches are relatively unaffected by the problems with random measurement error in environmental measurements as discussed in the next paragraphs. These types of approaches are based on the assumption that factors that contribute to the transfer of PbS to indoor dust, in the analyzed subset of residences, are comparable in other residences in the community. The appropriateness of this assumption should be examined in the assessment.

### Regression Analysis

Regression analysis is one approach to estimating a  $M_{SD}$  value for a site if paired data for relevant media are available for a subset of the residences (*i.e.*, Pb concentrations in relevant environmental media that might contribute to PbD, measured at similar times, at the same residences). The simplest variation of this method uses only paired soil and dust data when PbS is known to be the primary source of indoor dust lead. In this case, the  $M_{SD}$  is estimated from the slope of the regression equation which represents an empirical estimate of the incremental change in indoor PbD concentration that is associated with a unit change in PbS concentration. If non-soil sources are suspected of contributing significantly to indoor PbD, multiple regression analysis of data on the contributing pathways can be considered. However, the development of statistical models to predict the impact of paint Pb levels and paint condition on Pb in house dust is likely to be problematic.

It should be kept in mind that even in scenarios in which soil appears to be the major contributor to Pb in indoor dust, a regression analysis of outdoor PbS and indoor PbD concentrations may result in a biased (low) estimate of the  $M_{SD}$  due to the effects of measurement error in fitting these models. Standard statistical theory for regression analysis assumes that independent variables (in the present case PbS levels) are known without error. When there is significant error in the independent variables, regression slopes will underestimate the true relationships (and intercept terms will be artificially elevated). In this context, measurement error represents the variability in empirical measurements of the soil levels or other "independent" exposure variables, compared to the "actual," but unobserved, levels contacted by children. This type of measurement error is

a broader concern than errors that may occur in sample collection or in the processing and chemical analysis of the samples. Examples of typical sources of measurement error that should be considered when exploring PbS and PbD relationships include: (1) the soil particle size fraction contributing to indoor dust may not be the same fraction that is sampled and sieved to estimate PbS concentrations; (2) the soil sampling locations in a residential yard may not be the same locations where children (and pets) primarily contact soils which are subsequently transported indoors; and (3) neighboring properties and other community soil sources may contribute to indoor dust. The above sources of measurement error will introduce a negative bias into the estimate of the  $M_{SD}$  derived from a regression analysis; that is, they will contribute to a reduction in both the regression slope and correlation estimates for indoor PbD and outdoor PbS concentration relationships. Use of an underestimate of the  $M_{SD}$  in the IEUBK *Multiple Source Analysis* would result in an underestimate of indoor PbD concentrations (Equation 1).

### Lead Speciation

Chemical speciation and physical examination of particulates in house dust may support more direct approaches to determining the contribution of soil derived Pb in house dust. Several methods involving different levels of complexity can be considered. While these methods would require further research and evaluation, they have much potential to strengthen site specific estimates of  $M_{SD}$ .

- Analyses using tracer elements and/or particle speciation could be developed to directly estimate fractional amount of soil derived dust that is present in house dust without reliance on Pb measurements.
- Particle identification and micro analytical techniques could be applied to estimate the contribution of dust from lead-based paint to the total Pb content of house dust. If lead-based paint is the major non-soil contributor to house dust, the residual Pb would be attributable to soils.
- Source apportionment of indoor PbD may be possible in some residential scenarios by comparing elemental fingerprints of lead-bearing particles in indoor dust to characteristic fingerprints of source materials (Hunt *et al.*, 1993). If lead-bearing particles in dust are found to be characteristic of soil sources, this approach could be used to estimate the relative contributions of soil sources to total indoor PbD, and, accordingly, support estimation of  $M_{SD}$ . The approach would require the development of a library



of characteristic fingerprints for possible sources of indoor PbD at the site, in addition to soil sources, since there will be some overlap in the elemental compositions of various sources. Complications will arise where different site soils diverge in their mineralogical composition.

### **Applications of the $M_{SD}$ to Baseline Lead Risk Assessments**

The TRW recommends using measured indoor PbD concentrations in risk assessments for estimating Pb intake from exposure to indoor dust. If adequate PbD concentration data are available, these data may be used as inputs to the IEUBK model rather than using the *Multiple Source Analysis* menu options (including the  $M_{SD}$ ). In situations where indoor dust sampling is precluded or data gaps exist, calculations using  $M_{SD}$  may be used to estimate likely PbD concentrations under appropriate circumstances. However, site risk assessments should consider all potential sources of indoor PbD such as exterior and interior lead-based paint, deposition of non-soil airborne particulates, and outdoor soil.

### **Applications of the $M_{SD}$ to Soil Lead Cleanup Goals**

Unlike Pb risk assessments, in which measured indoor PbD concentrations are preferentially used over estimates based on the  $M_{SD}$ , PbS cleanup goals require assumptions about the soil-to-dust transport pathway, and other pathways that may contribute PbD after remediation is completed. The default value of 0.70 for the  $M_{SD}$  is intended to be representative of the mass fraction of soil in indoor dust for typical residences. As described previously in the *Background* section, there are many factors that may influence the transport and deposition of soil-derived dust into the indoor environment, and there is usually limited information on the effects that soil remediation might have on these factors. For example, at most sites, it would be difficult to predict what impacts remediation would have on the transport of soil into homes, unless the quantitative impacts of remediation on the principal factors that influence soil transport could be assessed. If site specific estimates of  $M_{SD}$  are developed, careful consideration needs to be given to the methodological issues that were previously discussed. In setting remediation goals, consideration also needs to be given to the impact of non-soil sources of dust lead. Soil lead exposures will generally present additional risks to children who also have Pb exposures from other sources (e.g., dust from lead-based paint). The Superfund Lead Directive (OSWER Directive #9355.4-12) provides

important guidance relevant to these issues.

### **RECOMMENDATIONS**

The TRW recommends that measurements of Pb concentrations be used as inputs to the IEUBK model when conducting residential Pb risk assessments. In the absence of site-specific data on PbD concentrations, the *Multiple Source Analysis* may be used with a default estimate for  $M_{SD}$  of 0.70. The TRW recognizes that the  $M_{SD}$  value may vary depending on site-specific factors that control the transport, deposition, and removal of soil and other sources of indoor dust. If there is compelling evidence to suggest that the mass fraction of soil in indoor dust differs from 0.70, this information should be presented in the risk assessment. Given the complexity of the dust exposure pathway, the TRW further recommends that, for the time being, EPA assessors and managers seek TRW review of site  $M_{SD}$  values when considering using values other than the IEUBK model default of 0.70 (for use in either baseline risk assessment or for estimating soil cleanup levels). At the present time information is limited regarding both the practical applications of techniques to estimate  $M_{SD}$  and the range of valid values for this parameter. The review of additional site data will also assist the TRW in providing further guidance regarding a plausible range of values for  $M_{SD}$ . The TRW will appreciate receiving feedback from model users regarding the technical guidance provided in this document as well as their experiences in addressing  $M_{SD}$  at Pb sites.

### **REFERENCES**

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